

CLAIMS

1. A method for liquefying a gas which comprises cooling a feed gas stream successively through first and second temperature ranges to provide a liquefied product, wherein refrigeration for cooling the feed gas stream in the first temperature range is provided by a first vaporizing refrigerant and refrigeration for cooling the stream in the second temperature range is provided by a second vaporizing refrigerant, and further wherein an auxiliary refrigerant derived from the second vaporizing refrigerant provides additional refrigeration by vaporization at temperatures above a lowest temperature in the first temperature range.
2. A method for liquefying a gas which comprises cooling a feed gas stream (1) successively through first, second, and third temperature ranges to provide a liquefied product (13), wherein refrigeration for cooling the feed gas stream in the first temperature range is provided by a first vaporizing refrigerant (117), refrigeration for cooling the stream in the second temperature range is provided by a second vaporizing refrigerant (213), and refrigeration for cooling the stream in the third temperature range is provided by a third vaporizing refrigerant (315), and further wherein an auxiliary refrigerant (373, 377) derived from the third vaporizing refrigerant (315) provides additional refrigeration by vaporization (357, 379) at temperatures above a lowest temperature in the second temperature range.
3. A method for liquefying a gas which comprises cooling a feed gas stream successively through first and second temperature ranges to provide a liquefied product by
- (a) providing refrigeration for cooling the stream in the first temperature range by vaporizing a first refrigerant;
 - (b) providing refrigeration for cooling the stream in the second temperature range by vaporizing a first portion of a second refrigerant at a first pressure; and

(c) providing additional refrigeration at temperatures above a lowest temperature in the first temperature range by vaporizing a second portion of the second refrigerant at a second pressure.

5 4. The method of Claim 3 wherein the first pressure is lower than the second pressure.

5. A method for liquefying a gas which comprises cooling a feed gas stream (1) successively through first, second, and third temperature ranges to provide a liquefied product (13) by

10 (a) providing refrigeration for cooling the stream in the first temperature range by vaporizing a first refrigerant (117);

(b) providing refrigeration for cooling the stream in the second temperature range by vaporizing a second refrigerant (213);

15 (c) providing refrigeration for cooling the stream in the third temperature range by vaporizing a first portion (329) of a third refrigerant (369) at a first pressure; and

(d) providing additional refrigeration at temperatures above a lowest temperature in the second temperature range by vaporizing (357) a second portion (373) of the third refrigerant (369) at a second pressure.

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6. The method of Claim 5 wherein the first pressure is lower than the second pressure.

7. The method of Claim 5 wherein the first refrigerant (117) is a single component refrigerant.

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8. The method of Claim 5 wherein the second (213) and third (315) refrigerants are multi-component refrigerants.

9. The method of Claim 5 wherein the first temperature range is between 35°C and –70°C, the second temperature range is between 0°C and –140°C, and the third temperature range is between –90°C and –165°C.

5 10. The method of Claim 5 wherein the feed gas stream (1) is natural gas.

11. The method of Claim 5 wherein the third refrigerant (369) is provided by

(1) compressing (359) and cooling (363) a vaporized refrigerant (329) to provide an intermediate compressed refrigerant (365);

10 (2) combining the intermediate compressed refrigerant (363) with an additional vaporized refrigerant (367) to provide a combined intermediate refrigerant;

(3) compressing (319) and cooling (320) the combined intermediate refrigerant to provide a cooled compressed refrigerant (328); and

15 (4) further cooling and condensing (357) the cooled compressed refrigerant (328) to provide the third refrigerant (369), wherein the refrigeration for the cooling and condensing (357) is provided by vaporizing the second portion (373) of the third refrigerant (369) at the second pressure.

20 12. The method of Claim 11 wherein the cooling (320) of the first compressed vapor yields a two-phase stream, and the method further comprises separating (321) the two-phase stream into a vapor stream (322) and a liquid stream (323), compressing (324) the vapor stream (322) to yield a further compressed vapor, pumping (325) the liquid stream (323) to provide a pressurized liquid, combining the further compressed vapor and the
25 pressurized liquid to yield a combined refrigerant stream (326), and cooling the combined refrigerant stream (326) to provide the cooled compressed refrigerant (328).

30 13. A method for liquefying a gas which comprises cooling a feed gas stream successively through first and second temperature ranges to provide a liquefied product by

(a) providing refrigeration for cooling the stream in the first temperature range by vaporizing a first refrigerant;

(b) providing refrigeration for cooling the stream in the second temperature range by vaporizing a second refrigerant; and

5 (c) providing additional refrigeration at temperatures above a lowest temperature in the first temperature range by vaporizing an auxiliary refrigerant derived from the second refrigerant.

14. A method for liquefying a gas which comprises cooling a feed gas stream (1)
10 successively through first, second, and third temperature ranges to provide a liquefied product (13) by

(a) providing refrigeration for cooling the stream in the first temperature range by vaporizing a first refrigerant (117);

15 (b) providing refrigeration for cooling the stream in the second temperature range by vaporizing a second refrigerant (213);

(c) providing refrigeration for cooling the stream in the third temperature range by partially or fully vaporizing a third refrigerant (315); and

20 (d) providing additional refrigeration at temperatures above a lowest temperature in the second temperature range by vaporizing (379) an auxiliary refrigerant (377) derived from the third refrigerant (315).

15. The method of Claim 14 wherein the first refrigerant (117) is a single component refrigerant.

25 16. The method of Claim 14 wherein the second (213) and third (315) refrigerants are multi-component refrigerants.

17. The method of Claim 14 wherein the first temperature range is between 35°C and –70°C, the second temperature range is between 0°C and –140°C, and the third
30 temperature range is between –90°C and –165°C.

18. The method of Claim 14 wherein the feed gas stream (1) is natural gas.

19. The method of Claim 14 wherein the auxiliary refrigerant (377) is provided by

5 (1) partially or fully vaporizing (312) the third refrigerant (315) to provide a partially or fully vaporized warmed refrigerant (316); and

 (2) combining the warmed refrigerant (316) with a cooled reduced-pressure (375) refrigerant to provide the auxiliary refrigerant (377);

and wherein the cooled reduced-pressure refrigerant is provided by

10 (3) vaporizing (379) the auxiliary refrigerant (377) to yield a vaporized auxiliary refrigerant (381);

 (4) compressing (319) and cooling (320) the vaporized auxiliary refrigerant to provide a cooled, compressed, partially-condensed auxiliary refrigerant (328);

15 (5) separating (330) the cooled, compressed, partially-condensed auxiliary refrigerant (328) into a liquid fraction (383) and a vapor fraction (385);

 (6) further cooling the liquid fraction (383) by indirect heat exchange with the vaporizing (379) auxiliary refrigerant to provide a cooled liquid refrigerant (389); and

20 (7) reducing the pressure (375) of the cooled liquid refrigerant (389) to provide the cooled reduced-pressure (375) refrigerant.

20. The method of Claim 19 wherein the cooling (320) of the first compressed vapor yields a two-phase stream, and wherein the method further comprises separating (321) the two-phase stream into a vapor stream (322) and a liquid stream (323), compressing
25 (324) the vapor stream (322) to yield a further compressed vapor, pumping (325) the liquid stream (323) to provide a pressurized liquid, combining the further compressed vapor and the pressurized liquid to yield a combined refrigerant stream (326), and cooling the combined refrigerant stream (326) to provide the cooled, compressed, partially condensed auxiliary refrigerant (328).

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